DISCOID CRINOIDAL ROOTS AND CAMAROCRINUS

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Since the writings of Wachsmuth and Springer,[1] and of Bather[2] have given an increased scientific interest to fossil Crinoidal roots or stem bases, fossils of this sort which occur in the Galena (Trenton) stage of the Ordovician in Minnesota, have been collected by me with some especial care. In particular, certain disc-shaped roots have been collected and studied. These are believed to represent the primitive form and structure of Crinoidal roots, and are of special interest for that reason, as also because they are rare and little known. Few fossils of this kind have been described heretofore. Since my collection represents a relatively large number, about 100 specimens, and since they afford some new information regarding the structure and relationship of such Crinoidal roots, description and discussion of them is here offered.

The specimens in hand are discoid or conical with flat base, or bent from that form when the surface to which the base had attached is not plane. They are found adhering to shells, Monticuliporoid stalks, Crinoid stems and especially to pebbles. They consist of polygonal calcite plates in the manner of Echinoderms in general. The center or apex of the cone bears a scar with central perforation. This scar is like those which are characteristic of Crinoidal roots and shows where a Crinoidal stem has been detached. In a few cases an attached stem fragment remains.

Among the specimens several species are represented, ranging in structure from those similar to the well-known *Lichenocrinus* on the one hand, and on the other to forms with lobate basal margin which link rather to the well-known and common form of roots with long, round cirri. Others tend to become globular and a relation to the problematical *Camarocrinus* is therefore to be considered.

[1] *The North American Crinoidea Camarata*, p. 49–51, 1897.

[2] *Geological Magazine*, Vol. V, p. 328, 1898.

PREVIOUSLY DESCRIBED FORMS

A few primitive Crinoidal bases have been heretofore described. James Hall noticed specimens from Trenton Falls in the Trenton limestone.[1] A drawing after Hall's figure *2a*, is reproduced here in Fig. 1. p. 243. His description of this and others merely states that they are "bases of attachment" "of the columns of some (uncertain) species of Crinoidea." Again James Hall described[2] specimens as occurring in the Niagara limestone, which may perhaps be well considered in this connection. One, represented by his Fig. 11, is described as "a fragment of a root with few radicles, ... showing a hexagonal canal," and the other, Fig. 10, is described as "a fragment of a root with numerous radicles." Those Figs. 11 and 10 are here represented by Figs. 2 and 3 respectively, by which their general character can be seen. Bather[3] calls attention to others which James Hall had described, in *Pal. N. Y.*, Vol. III, 1859, as *Aspidocrinus*, and of which Hall distinguishes three species, all from the Lower Helderberg, describing them on pp. 122–23, and giving figures of them, Plate V, Figs. 13–20. Hall appears much in doubt about their structure and relations. Neither his descriptions nor his figures are in any respect satisfactory. The fossils may, I think, rather be columnals, than bases.

From the Trenton limestone at Ottawa, Canada, Billings reports[4] certain specimens which should be noted. One specimen, represented in Fig. 1*g*, Plate V, *loc. cit.*, he says is "the base of the column" of *cleiocrinus regius* Bill. This specimen is not further described nor details of the root's structure shown. One may, however, infer that it is similar to that of the fragmental columns upon which he bases the species, *C. grandis* Bill.,[5] and of which he says, "The radix or base of attachment of the column consists of a number of large roots which appear to be composed of small polygonal plates." The figure of this one shows no more than the meager description gives,

[1] *Pal. N. Y.*, Vol. I, p. 86, Pl. XXIX, Fig. 2 *a*, *b*, 1847.

[2] *Pal. N. Y.*, Vol. II, p. 231, Pl. XLV, Figs. 10, 11.

[3] *Loc. cit.*

[4] *Canadian Organic Remains*, Decade 4, 1859.

[5] *Loc. cit.*, p. 54, Pl. V, Fig. *2a*.

except that the column and root appear sharply defined at their junction.

In a little later publication,[1] James Hall presents conclusive evidence of a fragment of Crinoidal stem attached to a discoid base. The stem and therefore the base is identified as belonging to a particular species of Crinoidea, i. e., *Calceocrinus (Cheirocrinus) clarus* (Hall). These fossils come from the Silurian Niagara group. The base is similar to Fig. 1 and Figs. 6 and 7. Another base to which a fragment of stem remains attached is described from the Ordovician in the upper part of the Cincinnati group, at Cincinnati, Ohio, by F. B. Meek.[2] He says that it probably belongs to *Anomalocrinus incurvus* M. & W. It "consists of a solid expansion near an inch in diameter, with irregular margins." "It has a short piece of the column attached, which rises abruptly from the expansion, and is composed of very thin anchylosed segments, showing the appearance of being each made up of numerous little pieces, ... " i. e., like stems of *A. incurvus* M. & W. Fig. 4 and 5 here are drawn after his figures 6 *d*, *c*.

Wachsmuth and Springer,[3] say that "in the Hudson River group of Cincinnati, we occasionally find Crinoidal disks attached to pieces of coral, which closely resemble the dorso-central of *Antedon.* These disks have a pit or depression at the middle of the upper face, sometimes inclosing a small stem joint. They are irregularly round, and some of them have small processes passing outward from the sides which seem to represent primitive cirri (Plate I, Figs. 9, 10)." Drawings after their Figs. 9, 10, are given here in Figs. 6, 7. Opposite Plate I, in the description to Figs. 9, 10, they say "dorso-central plates, supposed to belong to a species of *Heterocrinus.*" Wachsmuth and Springer consider the roots as having separated from the stem during the life of the Crinoid.

In a former paper on "A New Cystocrinoidean Species from the Ordovician,"[4] I have described a few specimens of discoid roots which were found associated with *Strophocrinus dicyclicus* Sar.,

1 *Fifteenth Rep. N. Y. State. Cab. Nat. Hist.*, Pl. I, Figs. 17, 18, 1862.

2 *Geol. Sur. Ohio*, Vol. I, "Paleontology," p. 18, Pl. II, Fig. 6, *d*, *e*, 1873.

3 *Op. cit.*, p. 49.

4 *American Geologist*, Vol. XXIV, pp. 263–76, 1899.

and which probably belong to that species. Three figures published[1] are reproduced here as Figs. 8, 9, 10.

Associated with discoid Crinoidal roots, in the Ordovician are the similar fossils known as *Lichenocrinus*. Several species of these have been described with such thoroughness, especially by Meek,[2] and with such citations as to make a review of the genus here seem unnecessary. The crateriform bases of these fossils are known to bear a slender stalk of polygonal plates in some cases. Yet this stalk is not known to have been identified, with certainty, as a Crinoidal structure. *Lichenocrinus* can be treated only as a problematic structure, notwithstanding concise knowledge of the fossils as they occur, and it may therefore be quite neglected here. In a large number of specimens of it which I have collected, nothing new has appeared. In regard to the discoid Crinoidal roots on the contrary, their structure has not been thoroughly described and they invite further study n this respect, as well as identification with recognized species of Crinoidea.

NEW DESCRIPTIONS

In order to facilitate scientific description a generic name is used here to include several taxonomic species of Crinoidal roots. This generic name, as in case of *Lichenocrinus* and of *Camarocrinus*, is not expected to coincide with any one generic term based upon described crowns and will be superseded by such generic terms as often as root structures are identified specifically with previously described crowns.

PODOLITHUS n. gen.

Primitive discoid or conical Crinoidal root-structures with more or less lobate margins and with a fixing-plate. Region about the stem-scar not depressed. Type *Podolithus schizocrinus*, n. sp., Fig. 11.

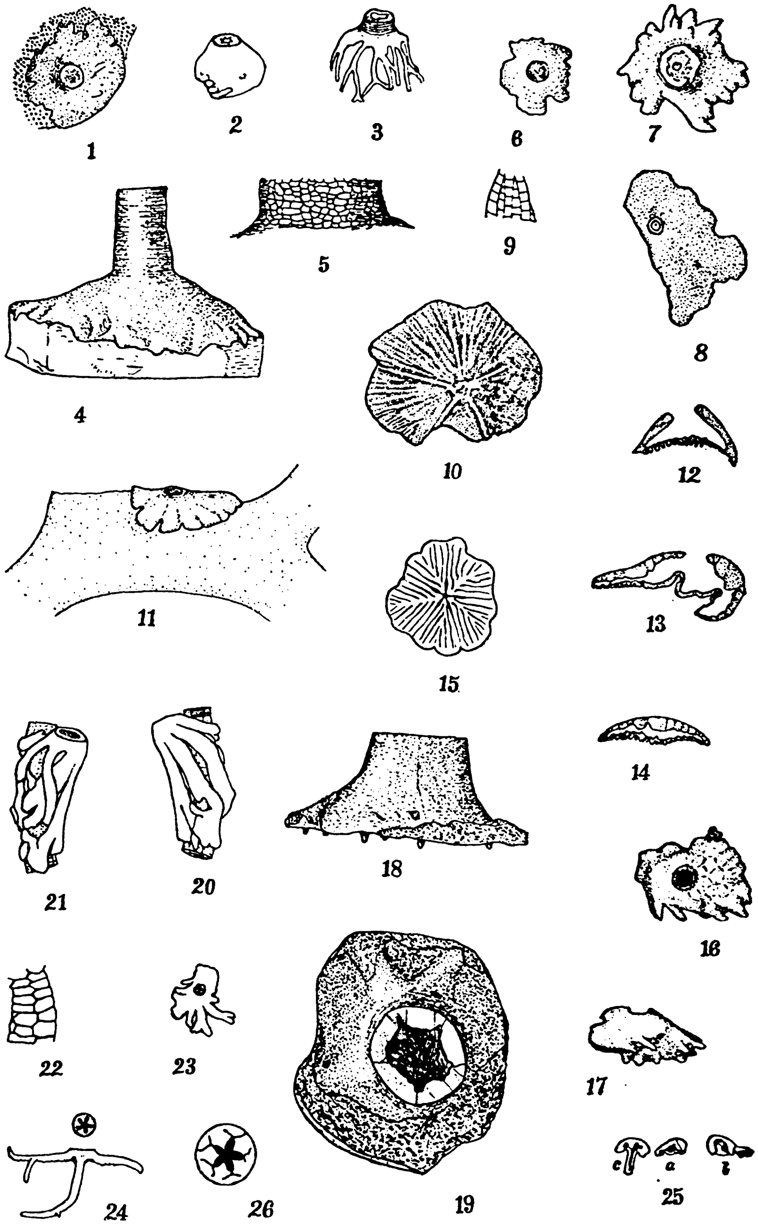
Podolithus strophocrinus nom. nov.

(Figs. 8, 9, 10)

To this type belong stem-bases which are low, conical, 1 to 5^{cm} in diameter, with nearly entire margin and generally circular outline, although by accident sometimes quite irregular. Fig. 8 shows the most unsymmetrical specimen found, while Fig. 10 represents one

[1] *Op. cit.*, Pl. XII, Figs. 14, 15, 16. [2] *Op. cit.*, pp. 44–52.

FIGS. 1–26



which although circular, appears not to be so because the margin is bent under. In the fossils, the stem is wanting, but from the scar it is seen to have been slender. The upper surface is smooth when well preserved. Suture lines show indistinctly that there are quadrangular plates, generally in rows, Fig. 9, arranged radially. Five rows of plates radiate from the center and between these other rows gradually intercalate. The interior is separated into canal-like spaces by partitions which appear to be inward thickenings of the plates, traversing the same along the rows radially. This structure has been seen by means of macerated and weathered specimens only, as is shown in Fig. 10, and the extension downward of the partitions is not exactly determined; but these probably touch the ground layer or fixing plate.

This type of Crinoidal root is remarkable for its large radius, small height, and relatively small stem-scar. A number of specimens were found at a particular part of a quarry where plates of *Strophocrinus* were abundant, and they are all believed to be structures of one species, i. e., *Podolithus strophocrinus*=*Strophocrinus dicyclicus*. These bases and the plates of *Strophocrinus* are otherwise rare. Their occurrence is in association with intra-formational conglomerate at the top of zone No. 4 (Stictopora bed) and in zone No. 5 (Fucoid bed) of the Galena-Trenton stage, at St. Paul, Minn. In view of their large size and close association with crown plates, it appears to be most probable that the bases were permanent anchors.

Podolithus schizocrinus n. sp.

(Figs. 11–17)

This species includes stem-bases which are from 3^{mm} to 2^{cm} in diameter, about one-fourth as high as wide, and in general outline conical but with thick and irregularly lobed margin (Fig. 11). The apex of one small specimen shows a flat circular stem-scar, with a star-shaped lumen, while others seem to have been either excessively macerated or reabsorbed in this part. Generally there is a circle of small pores or canal ends seen just within the rim of the central opening. No other openings through the wall appear anywhere. The top surface is dense and smooth with indistinct sutures. Transverse thin-section reveals, under the petrographic microscope, that

the top consists of calcite plates, increasingly numerous in larger specimens (Figs. 12 and 13). The plates are hexagonal to quadrangular, and arranged radially in short intercalating rows. The inner part of the plates appears in thin-section less dense than the outer, and is rough surfaced. Radiating ridges are also evident (Fig. 14), on the inside. Maceration may have reduced them, but they are not now seen to touch the fixing plate.

The fixing plate is thin and closely knit to the surface of support. It is a single large plate, united by suture only around the periphery of the root. On the upper surface of the fixing plate there are raised lines or ridges. These are well seen in one specimen from which the top plates are partly broken off, and in several others which have been weathered. None are complete, and a diagram (Fig. 15), is given, for the sake of completeness and clearness also, instead of a drawing of a single specimen. There is a central sharp elevation, from which radiate five angular ridges, and these are widest and highest at a short distance from the center. Other ridges intercalate, chiefly in diverging pairs, and all diminish in intensity toward the periphery.

The internal structure might be quite geometrically symmetrical if the external form were so, but in every specimen the place of growth has modified the form of the root more or less. The fixing-plate follows closely the surface of support, whose irregularities are reflected within. Again, some specimens have the stem-scar near or at one side, and directed obliquely to that side as if the surface of support had been vertical or inclined, the stem too having been vertical. In those cases the longer side is in every way the more developed. Figure 13 shows a root which had grown over the edge of the supporting object.

Figs. 16 and 17 represent a specimen which has grown on a slender branch of *Pachydictya acuta* Hall and surrounded it, the fixing-plate thence having bedded to an irregular, probably muddy, surface. The marginal lobes are extended as round short roots. Two of these, which are cleaved off, show central circular canals. One other specimen which was found near this one has grown in a similar way but has flat areas around the top.

This type of discoid base I find in greater numbers and through

greater range and wider distribution than any other. At Minneapolis and St. Paul it has been found in the Galena-Trenton in zone No. 4. (Stictopora bed) (Figs. 11, 12, and 15), in zone No. 5. (Fucoid bed) (Figs. 13, 14), and in zone No. 6. (Orthisina bed), and at Kenyon, Minn., also in zone No. 6 (Figs. 16, 17). Those from the Trenton of New York, as described by Hall (see Fig. 1), may belong to the same. In their occurrence they are associated with stems and crowns of *Schizocrinus*, to which they may belong. No other Crinoidal stems and plates are as abundant and no others are known in each bed. From the reabsorbed appearance of the stem-scar, as compared with other parts of the root in all sizes of specimens, I am led to adopt further the interpretation that the stems were loosed from the root at any convenient time during the animal's life.

Podolithus Anomalocrinus n. sp.

(Figs. 18, 19)

This species is known by a single specimen from zone No. 6 (Orthisina bed) of the Galena-Trenton, below Mantorville, Dodge Co., Minn. The specimen is a root with a fragment of a large stem with large lumen. From the stem to the margin its top surface is concave. The specimen is now free, although the fixing-plate on its under side bears a distinct impression from a former attachment upon a nearly flat surface. This impression shows quadrangular figures in transverse rows, and appears to be that of the inside of a *Receptaculites*. Short blunt processes occur at the angles where canals would run through that wall of *Receptaculites*. This impression indicates, I think, that the root grew on an intra-formational conglomerate pebble, which consisted of a fossil *Receptaculites*. Such fossils with more or less of adhering matrix are not uncommon as pebbles in that zone.

The margin of the root forms a sharp, slightly serrate edge in one place (left side of Fig. 19); in another it is abruptly turned upward, right side, and for the rest it appears to be overturned upon the top surface. The overturned part has a spongy-looking surface. Evidently the root was accidentally restricted in its growth. If it had not been, then the specimen would have resembled more closely the one described by Meek (see Fig. 4). The margin would have probably been five-lobed, corresponding to five prominences which radiate

from the rounded angles of the stem. As the specimen is, there appear distinct depressions of the top surface between the radial prominences where not covered by the overturned margin.

The stem's surface is marked by slightly raised transverse ridges, and a little weathering has brought intermediate rows of small pores to view. The exposed end of the stem shows numerous fine radiating anastomosing furrows, and a few larger ones. These were evidently canals between segments of the unbroken stem and the pores on the outer surface are obviously the ends of the same. The pores are united superficially by suture-like lines which give the stem the appearance of consisting of small plates. Meek describes a very similar structure in his specimen (see Fig. 5.). At each angle of the stem is a coarse suture. By observing these described marks, it is seen that the stem on my specimen extends down 5^{mm} from the top, and consists of about eight circles of thin undulating plates, which alternate in five vertical rows.

The surface below the stem shows faint close sutures, indicating that the top of the root proper is made up of numerous polygonal distributed plates.

Podolithus eucheirocrinus n. sp.

(Figs. 20–23)

This species includes bases, the conical form of which is concealed more or less by long root-like lobes of the margin. The largest specimen is grown around a Crinoid stem so that the lobes or radicles extend across one another (Figs. 20, 21). One small specimen has grown obliquely on a curved surface and has the lobes at the sides and lower margin only well extended (Fig. 23). The top or outer surface is dense, and consists of polygonal plates, though the sutures are in part indistinct. About the stem-scar the plates appear subhexagonal, alternating in radial rows, while on the lobes or radicles and their branches, the plates are transversely elongated and alternate in two rows (Fig. 22). The radicles are flattened on top but convexed on the sides.

The stem-scar is obscured on each specimen, and no stem fragment being attached, identification of these roots with any columns is uncertain. They are associated with Crinoid columns like the one upon which a root has grown (Fig. 20), which has five rows of colum-

nals, nearly corresponding in circles. They are found in the upper part of zone No. 4 (Stictopora bed), where specimens figured were found, and in the base of zone No. 5 (Fucoid bed) of the Galena-Trenton stage at St. Paul, Minn. The only probable related calyx is that of *Eucheirocrinus punctatus* (Ulr.) which has the same range, and although pieces of stem one-half inch long attached to them have oval rings yet, in view of the great differences known to mark Crinoidal columns, the lower part of the same might be the one under consideration.

Podolithus dendrocrinus n. sp.

(Figs. 24, 25, 26)

This species comprises roots in which the discoid or conical form is concealed, but in which the structure remains. They occur attached to hard surfaces with one to five simple or branched radicles of various lengths. Fig. 24 is of the largest specimen. One of its radicles curves downward. The radicles or lobes are smooth and quite round, excepting the under side by which they are attached. Seen from the upper side they consist of narrow transverse rings, but a thin-section shows that these are interrupted by the fixing-plate which unites with them by suture. Fig. 25 shows the thin-section ×4. The section is cut across three lobes, *a*, *b*, *c*, each of which attaches to the same Monticuliporoid stock. Fig. *a* cuts obliquely, striking two plates above, while *b* cuts a bifurcation. The fixing-plate in *c* penetrates a cell of the Monticuliporoid at that point. Compare Fig. 18. The lumen is represented in black.

The stem-scar is preserved in several cases and clearly shows a stellate lumen and radiate ligamental scars. Certain cylindrical Crinoid columns are found in the same strata and are easily matched with these though generally larger in size. Fig. 26 represents the end of such a column ×2 without the radiating striae, about 75 in number, which are omitted. It shows the lumen and ten distinct canals which run in the joint and in part thence through the segment. On the outer surface, the canals appear as distributed pores. The same canals are seen at the stem-scar of the roots, but I cannot find them lower on the disk or its lobes.

These roots and columns occur rarely in zones Nos. 4, 5, and 6, of the Galena-Trenton stage. Figs. 24, 25, 26, are of specimens

from zone No. 5, at St. Paul, Minn. An associated species of *Dendrocrinus* was the probable possessor of them.

DISCUSSION

In collecting specimens, I have not only obtained well-preserved materials for the study of structures, but have tried also to find means for identification of them. A root with entire column and crown has not been found, and should scarcely be expected to occur where all Echinodermal remains were badly scattered. But, roots and associated stems can be matched with crowns more or less successfully and careful effort to do this has been made.

From the evidence which is afforded by the described specimens, it may safely be concluded that these discoid stem-bases belong to Crinoidea, and admitting circumstantial evidence, the conclusion is imminent that they also belong to a diversity of Crinoidea. *Calceocrinus*, *Eucheirocrinus*, *Heterocrinus*, and *Anomalocrinus* belong to Bather's Order, Monocyclica Inadunata; *Schizocrinus* to Order, Monocyclica Camerata; *Dendrocrinus* and *Strophocrinus* to Order, Dicyclica Inadunata. To the circumstantial evidence may be added the fact that certain Cystidea have similar structures, the fixing-plate in *Lepidodiscus*, which I have collected here, being very like those of the Crinoidal discoid bases. This tends to prove that this structure is primitive and might persist in diverse lines of Crinoidal evolution.

As to structure, there is conclusive evidence that the fixing-plate in *Podolithus* is a single piece, while the top of the root is perhaps always of many plates. If I understand rightly, Wachsmuth and Springer[1] considered the entire root or discoid base as a single plate and compared it to the "dorso-central" plate of *Antedon*. Whether the fixing-plate or the entire root should be now called dorso-central, or perhaps neither comparison be made, I am not able to decide. Again the interior presents always, as far as known, raised radiating structures upon the fixing-plate and under the top plates, resembling *Lichenocrinus* in the latter. Also as in *Lichenocrinus*, no pores or canals to the exterior are seen aside from the stem-lumen and scar, even though attached columnals present external pores. Accidental

[1] *Op. cit.*

penetration of foreign substances into the root are probably always walled off from the internal cavity.

The described new species of *Podolithus* with species of *Lichenocrinus* include all the Crinoidal roots which are known to me to occur in the Galena-Trenton stage. Together they form a series which may illustrate the early evolution of Crinoidal roots from a primitive conical expansion of distributed polygonal plates, over a large circular fixing-plate, to a lobate form with plates in single rows over a deeply cut fixing-plate. Further reduction of the fixing-plate could produce the commonly known cirri with circular, perforated segments.

COMPARISON WITH *Camarocrinus*

At first sight, the discoid roots appear to differ greatly from *Camarocrinus*, but upon close comparison they are much more alike, the latter being a modified form of the former. Before trying to show this, the problem concerning *Camarocrinus* alone requires attention. That problem appears in the recently published work *On Siluric and Devonic Cystidea and Camarocrinus*, by Charles Schuchert.[1] In this work *Camarocrinus* is discussed in regard to history of the genus, mode of occurrence of fossil specimens, their structures and possible relationships. The discussion appears to be quite exhaustive and the description of the fossils, very thorough. The work is based upon a wealth of best materials of all three known species,[2] two of which Schuchert redescribes and one of which he presents as new. I may say further that nothing new or not described by Schuchert was found by me in materials which were obtained through the kindness of Mr. Schuchert and of Mr. Bassler of the U. S. National Museum. Following his thorough discussion Schuchert says in the summary:[3] "The writer realizes that the last word has not been said in regard to *Camarocrinus*, and the present work is offered with the hope that some paleontologists will attack the problem from another point of view."

Schuchert's statement just quoted follows paragraphs in which the belief is expressed, following the opinion of James Hall and other

[1] "Smithsonian Miscellaneous Collections," Vol. XLVII, Part 2, 1904.

[2] A fourth species, *C. asiaticus* Reed, has been later described. See *Paleontologia Indica*, New Series Vol. II, Memoir No. 3, 1906, p. 88.

[3] *Op. cit.*, p. 269.

authors, that the *Camarocrinus* structures were roots of Crinoids, serving as floats, from which the stems had parted before their sinking to place of rest. Bather[1] had stated a little more in particular, and Schuchert quotes him as saying of these fossils, that, "another curious modification, perhaps connected with a free-floating existence, was presented by the root of *Scyphocrinus* [=*Lobolithus*=*Camarocrinus*]." Schuchert's discussion, as I read it, throws a shadow over the grounds upon which Bather may have based his belief concerning *Scyphocrinus*, and tends to leave the fossil *Camarocrinus* as problematic as when James Hall first described it.[2]

Authorities agree, in short, upon these peculiar balloon-shaped fossils being the modified root-structures of some Crinoid or other. It may also be taken as evident that they floated. The unsolved problem concerns their origin, the interpretation of their structural parts, and their relation to any particular species of Crinoids.

Camarocrinus appears not to have been considered from the side of the known Crinoidal discoid roots. The nearest approach to such a point of view is the suggestion which will be here quoted about *Lichenocrinus* and in which Schuchert makes really no progress toward the solution of the problem. "*Lichenocrinus* represents the nearest approach of a modified Crinoid root to *Camarocrinus*. It, too, is camerate, the radiating striae seen on weathered examples being vertical plates extending upward from the attached base to the inner side of the surface plates."[3] Again, p. 269, "this form when compared with *Camarocrinus* is wholly different, as the base of *Lichenocrinus* is attached to foreign bodies. . . . ." Bather, too, cites *Lichenocrinus* as a Crinoid root[4] yet it is quite as problematic as *Camarocrinus*. Moreover, the comparison of the camarae of *Camarocrinus* with the camerate structure of *Lichenocrinus*, as just quoted, is not the right view, as I shall endeavor to show.

To explain the origin and homologies of *Camarocrinus*, I wish rather to compare it with such discoid roots as are here described, e. g.,

[1] *Treatise on Zoölogy*, Vol. III, "Echinoderma," p. 135 (1900).

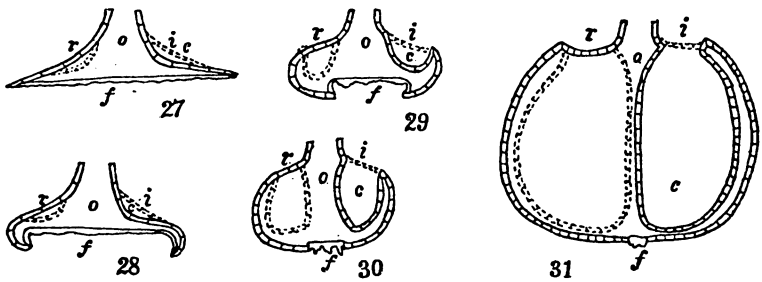
[2] More recently, Butler has found further evidence in support of his view, in the association of *Scyphocrinus* and *Lobolithus* remains in Silurian rocks of Cornwall. See Transactions of the Royal Geological Society of Cornwall, Vol. XIII, Part III, pp. 191–97, 1907.

[3] *Op. cit.*, p. 268. [4] *Op. cit.* p. 133.

Figs. 11, 13, 17, and 18. These bases are evidently very plastic to environmental conditions and certain characters in them if increased under exceptional conditions might well have changed to such as *Camarocrinus* possesses. Those characters are the occasionally turned-under margin (Fig. 13), and the five or more depressed spaces of the top surface (Fig. 19). These depressions may be termed inter-radicle pockets, since they lie between the main canals and lobes which radiate from the corners of the stem and lumen, or between branches of the same, all of which may be termed radicles.

A series of diagrams are given here to help show the probable origin of *Camarocrinus* (Fig. 31) from a discoid root (Fig. 27).

FIGS. 27–31



Taking the pentameral symmetry as typical, then a vertical section passing through a radicle, *r*, on one side, would cut the inter-radicle *i* on the other side. The respective inter-radicle and radicle contours, not cut by the plane of the section, are drawn in broken lines. Since *Camarocrinus* is supposed to have floated in inverted position, it should be represented so, except that comparison is easier when all figures correspond. Fig. 27 represents a known discoid base with normal, wide fixing-plate, *f*, and shallow, inter-radial pockets, *c*. Fig. 28 represents it with the margin turned under because of limited ground. Fig. 29 is an hypothetical representation of the same attached to a floating object by still more limited area, so that a smaller fixing-plate, *f*, and deeper pockets, *c*, result. Fig. 30 represents an adaptation where the supporting object and fixing-plate are less in surface and the pockets—gas filled—are enlarged. Fig. 31 represents *Camarocrinus* with fixing-plate, *f*, very small, not larger than other plates, while the pockets, *c*, are correspondingly enlarged and approximated.

The pockets or camarae of *Camarocrinus* are not internal divisions but invaginations of the outer wall, hence communicating not with the interior but the exterior. The internal partitions of *Podolithus* and of *Lichenocrinus*, too, correspond not with its "camarae" but with the canals of the interior, Fig. 27, and with partitions of the medio-basal chamber *o*, Fig. 31, and of other interspaces of the closely folded "double" wall. *Camarocrinus* is not to be considered as "double walled" but single walled. The wall, folded upon itself is united "by many short, stout, blunt processes,"[1] and these processes may be considered as homologous with the internal partitions of *Podolithus* and of *Lichenocrinus*. The inner surface of the wall of *Camarocrinus* is in fact marked by knoblike extensions, especially of the larger of the plates, and by pore-like enlargements of the sutures. Maceration and weathering must tend to open these latter, one after another, to the exterior. I am in doubt, therefore, whether the pores through the walls which Schuchert so clearly represents,[2] were originally open to the exterior or not. Presuming that they were, their nature may be the same as the pores on the column, though not seen on the base of *Podolithus anomalocrinus*. I have not discovered in the specimens of *Camarocrinus* the particular plate which is the original fixing-plate, but it might be seen on favorably young specimens.

Excepting possibly the supposed pores, the structures of *Camarocrinus* are those of *Podolithus*. Further, the observation may be made, that since *Schizocrinus* Hall and *Scyphocrinus* Zenker belong to the same family, *Glyptocrinidae* according to Bather, the probability that *Podolithus schizocrinus* belongs to the one, gives greater weight to the contention that *Camarocrinus* in part, at least, belongs to the other.

EXPLANATION OF FIGURES

Fig. 1.—Base of a Crinoidal column, on a coral, from the Trenton limestone; after Hall.

Figs. 2, 3.—Crinoidal roots from the Niagara limestone; after Hall.

Figs. 4, 5.—Root with fragment of column, from shales of the Cincinnati stage, and part of column of same, magnified; after Meek.

Figs. 6, 7.—Roots or "dorso-central plates," from shales of the Cincinnati stage; after Wachsmuth and Springer.

[1] Schuchert *op. cit.*, p. 263. [2] *Op. cit.*, Pl. XL, Figs. 8 10.

Figs. 8, 9, 10.—*Podolithus dicyclicus* nom. nov., from the Galena stage. Fig. 8, a well-preserved but unsymmetrical root; Fig. 9. part of surface of the same ×2; Fig. 10, a weathered specimen.

Figs. 11–17.—*Podolithus schizocrinus* n. sp., from the Galena stage. Fig. 11, a small root on a coral ×2; Fig. 12, vertical section of a similar one ×2; Fig. 13, vertical median section ×2, of a specimen which has overlapped the supporting coral; Fig. 14, section of same ×2, not median; Fig. 15, diagram of upper surface of fixing-plate with ridges; Figs. 16, 17, top and side views of a large specimen which has surrounded its attachment.

Figs. 18, 19.—*Podolithus anomalocrinus* n. sp. Side and top view of root and part of column; from the Galena stage.

Figs. 20–23.—*Podolithus eucheirocrinus* n. sp., from the Galena stage. Figs. 20, 21, views of a large lobate root surrounding a Crinoidal column; Fig. 22, part of surface of same ×2; Fig. 23 a small specimen.

Figs. 24, 25.—*Podolithus dendrocrinus* n. sp., from the Galena stage. Fig. 24, side view of root with long rounded lobes, and of stem-scar of same; Fig. 25, section ×4, across three lobes, *a*, *b*, *c*, of another specimen.

Fig. 26.—End of a round column ×2, showing lumen and canals; corresponding to Fig. 24.

Figs. 27–31.—Diagrammatic sections, Fig. 27, of *Podolithus*; Fig. 28 of same with margins turned under; Figs. 29, 30, hypothetical modifications; Fig. 31, of *Camarocrinus*; *f*, fixing plate; *o*, "medio-basal" cavity; *r*, radicle; *i*, interradicle contours; *c*, pockets or camerae.